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# WHAT'S NEW IN STRINGY SO(10) SUSY-GUTS

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As a stepping-stone in our search for string-derived three-generation SO(10) SUSY-GUTs, we investigated the six distinct gravitino generators $\boldsymbol{S}_i$ (see Table 1) in heterotic free fermionic strings and applied all consistent combinations of unique GSO projections (GSOPs) to them.[1] For each gravitino generator, we determined how many of the initial $N = 4$ spacetime supersymmetries (ST-SUSYs) can survive various combinations of GSOPs. Our findings can be summarized as follows (noting that a $\mathbb{Z}_n$ twisted boundary vector (BV) contains components of the form $\frac{2a}{n}$ where $a$ and $n$ are relative primes in at least one component):

1. Only left-moving (LM) $\mathbb{Z}_2$, $\mathbb{Z}_4$, and $\mathbb{Z}_8$ twists that correspond to automorphisms of $\mathrm{SU}(2)^6$ are consistent with $N = 1$ in free fermionic models. All other LM $\mathbb{Z}_n$ twists obviate $N = 1$. Thus, neither gravitino generators $\boldsymbol{S}_5$ and $\boldsymbol{S}_7$ (both with $\mathbb{Z}_6$ twists), nor $\boldsymbol{S}_{10}$ (with $\mathbb{Z}_{10}$ twists) can produce $N = 1$ ST-SUSY. $\boldsymbol{S}_5$ and $\boldsymbol{S}_7$ only result in $N = 4$, 2, or 0, whereas $\boldsymbol{S}_{10}$ yields $N = 4$ or 0.
2. $N = 1$ ST-SUSY is possible for $\boldsymbol{S}_1$, $\boldsymbol{S}_3$, and $\boldsymbol{S}_9$. Six general categories of GSOP sets for $\boldsymbol{S}_1$, three for $\boldsymbol{S}_3$, and one for $\boldsymbol{S}_9$ lead, respectively, to $N = 1$. The GSOPs in these sets originate from LM BVs with $\mathbb{Z}_2$, $\mathbb{Z}_4$, and $\mathbb{Z}_8$ twists.

We have completely classified the ways by which the number of ST-SUSYs in heterotic free fermionic strings may be reduced from $N = 4$ to the phenomenologically preferred $N = 1$. This means that the set of LM BVs in any free fermionic model with $N = 1$ ST-SUSY must be reproducible from one of the three specific gravitino sectors, $\boldsymbol{S}_1$, $\boldsymbol{S}_3$, or $\boldsymbol{S}_9$, combined with one of our left-moving BV sets whose GSOPs reduce the initial $N = 4$ to $N = 1$. The only variation from our BVs that true $N = 1$ models could have (besides trivial reordering of BV components) is some component sign changes, which we have shown do not lead to new, physically distinct models.

To this date, only the gravitino generator $\boldsymbol{S}_1$ has been used in actual $N = 1$ models. Reduction to $N = 1$ ST-SUSY has been accomplished through GSOPs from the NAHE set of boundary vectors.[2] Thus, our new results should be especially useful for model building when the NAHE set may be inconsistent with other

properties specifically desired in a model. This appears to be the situation with regard to current searches for consistent three generation SO(10) level-2 models. Initial results of this search were discussed in refs. 3 and 4. Attempts to simultaneously produce $N = 1$ ST-SUSY and a three-generation SO(10) level-2 grand unified theory, using for left-movers $\boldsymbol{S}_1$, the NAHE set, and one or two additional BVs containing some non-integer components, were initially thought to be successful. However, it was later discovered that the extra non-integer BVs required did not correspond to proper $\mathrm{SU}(2)^6$ automorphisms and, therefore, resulted in additional sectors containing tachyonic spacetime fermions.

Although we have found nine new solutions for generating $N = 1$ ST-SUSY, it remains to be shown that these are all physically unique from the standard NAHE set of GSOPs and boundary vectors. That is, we must check for instances when an $N = 1$ model that does not use the standard NAHE solution is phenomenologically equivalent to an $N = 1$ model that does. Identities relating partition functions for products of (anti)periodic worldsheet fermions to those for certain products of complex fermions have been derived.[5,6] These identities will be used to test for possible physical equivalences. Following this, we will investigate which of our physically unique LM $N = 1$ ST-SUSY solutions may be consistent with three-generation SO(10) level-2 GUT models.

**TABLE 1.**

| Class | Unique Massless Gravitino Boundary Vectors |
|---|---|
| $1\cdot1\cdot1\cdot1\cdot1\cdot1$ | $\boldsymbol{S}_1 = \{1,1 \quad (1;0,0)^6\}$ |
| $2\cdot2\cdot1\cdot1$ | $\boldsymbol{S}_3 = \{1,1 \quad (0,1;-\hat{\frac{1}{2}},\hat{\frac{1}{2}})^2 \quad (1;0,0)^2\}$ |
| $3\cdot1\cdot1\cdot1$ | $\boldsymbol{S}_5 = \{1,1 \quad (\hat{\frac{1}{3}},1;-\hat{\frac{2}{3}},0,0,\hat{\frac{2}{3}}) \quad (1;0,0)^3\}$ |
| $3\cdot3$ | $\boldsymbol{S}_7 = \{1,1 \quad (\hat{\frac{1}{3}},1;-\hat{\frac{2}{3}},0,0,\hat{\frac{2}{3}})^2\}$ |
| $4\cdot2$ | $\boldsymbol{S}_9 = \{1,1 \quad (0,\hat{\frac{1}{2}},1;-\hat{\frac{3}{4}},-\hat{\frac{1}{4}},\hat{\frac{1}{4}},\hat{\frac{3}{4}}) \quad (0,1;-\hat{\frac{1}{2}},\hat{\frac{1}{2}})\}$ |
| $5\cdot1$ | $\boldsymbol{S}_{10} = \{1,1 \quad (\hat{\frac{1}{5}},\hat{\frac{3}{5}},1;-\hat{\frac{4}{5}},-\hat{\frac{2}{5}},0,0,\hat{\frac{2}{5}},\hat{\frac{4}{5}}) \quad (1;0,0)\}$ |

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